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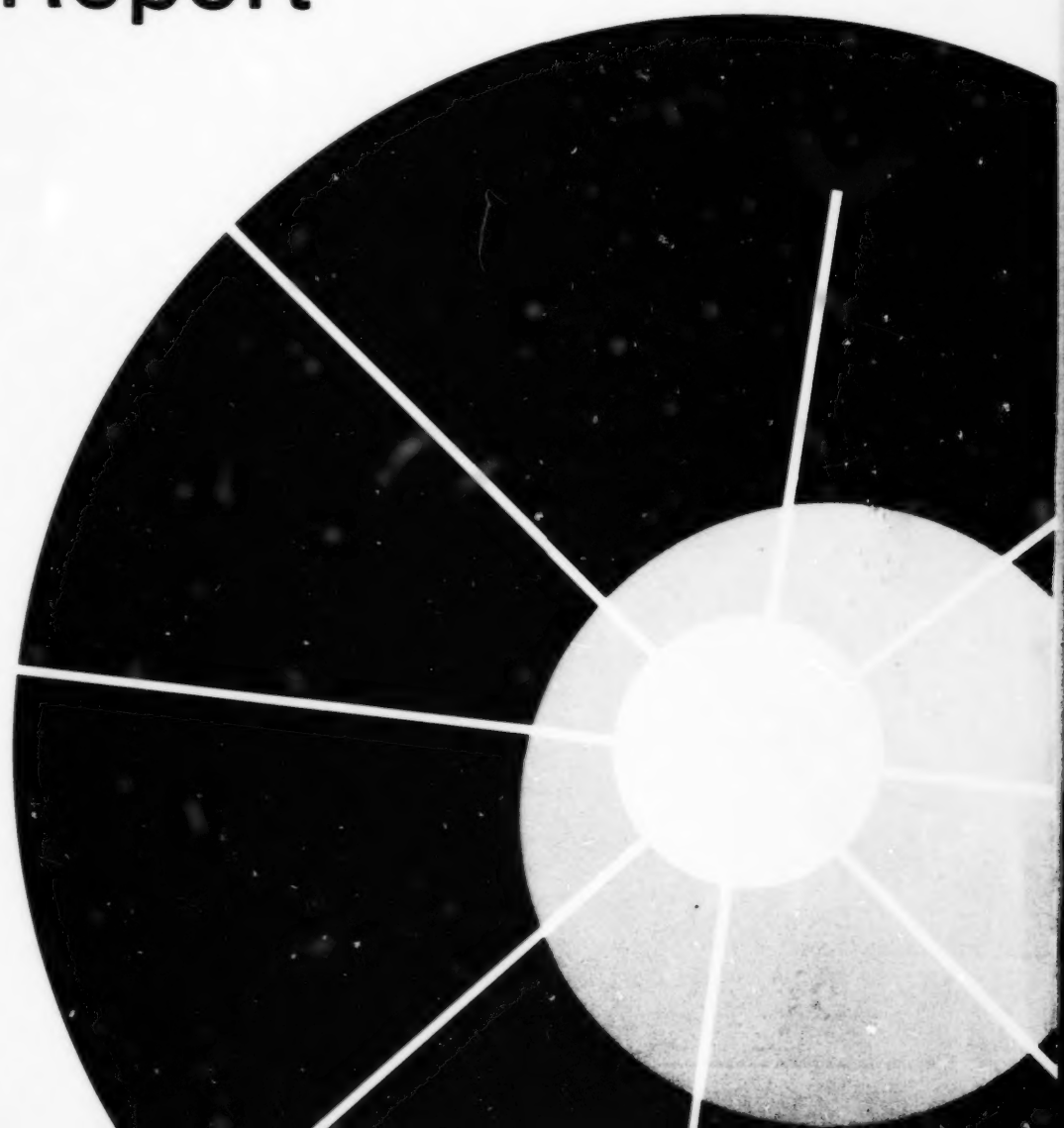
Canada - Saskatchewan Renewables — Conservation Demonstration Program

Final Report



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CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;
- To create employment in new or existing industries;
- To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Government of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

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Stack Gas Recycle in the Alfalfa Dehydration Industry

Final Technical Report
on a Renewables-Conservation Demonstration Program Project

Conducted By

North East Alfalfa Dehydrators Research Association

And Supported By

Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada

Project Leader: D.A. Pulkinen

Miscellaneous
Report FP-5

STACK GAS RECYCLE FOR ENERGY CONSERVATION IN THE ALFALFA DEHYDRATING INDUSTRY

A STUDY REPORT OF THE

NORTH EAST ALFALFA DEHYDRATORS

RESEARCH ASSOCIATION

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Tisdale, Saskatchewan

February, 1983

PREFACE

This report was prepared in partial fulfillment of a contract between the North East Alfalfa Dehydrators Research Association and the Province of Saskatchewan under the terms of the Canada-Saskatchewan Renewables-Conservation Demonstration Program.

In accepting this report, the Province of Saskatchewan agrees that the North East Alfalfa Dehydrators Research Association has fulfilled the requirement of the contract to provide a final report which contains all details of the work performed under the terms of the contract.

The Province of Saskatchewan, by accepting the report, does not make any warranty expressed or implied with respect to the accuracy or validity of the information contained in this report, nor does the Province of Saskatchewan assume any liability with respect to the use of, or actions resulting from the use of any information contained in this report.

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I. INTRODUCTION

A demonstration project was conducted to evaluate stack gas recycle in the artificial dehydration of alfalfa forage. The primary objectives of this study were: 1) to assess the operational and design characteristics required for satisfactory operation of a recycle system, 2) to determine the energy saving potential of stack gas recirculation, 3) to determine the economic potential of stack gas recycle, and 4) to determine other benefits that may be evident in the production of processed alfalfa products in Saskatchewan.

The project was conducted by the Alfalfa Dehydrators Research Laboratory of the N.E. Alfalfa Dehydrators Research Association, Tisdale, Sask. in co-operation with Parkland Alfalfa Products Ltd., Zenon Park, Sask. The Research Association acknowledges the financial support of Saskatchewan Mineral Resources and Energy, Mines and Resources Canada under the Canada - Saskatchewan Renewables - Conservation Demonstration Program. Also, appreciation is extended to Mr. A. Hesje and staff at Parkland Alfalfa Products for their assistance and co-operation in carrying out this project.

II. TECHNICAL BACKGROUND

A typical rotary drum dryer capable of evaporating 20,000 lb. water/hr. conveys 35,000 CFM of air through the dryer. This air, which contains products of natural gas combustion, water vapour and excess air (ambient air drawn in from front of furnace) is used as a medium for transferring heat to the alfalfa to facilitate drying, and secondly to convey the alfalfa through the dryer.

The amount of excess air entering the dryer varies inversely to the rate at which the dryer is being used. In other words, less excess air is required at high evaporation loading. The reason for this is that, since the primary fan displaces a constant volume, a higher evaporation load creates more expansion within the dryer and thereby reduces the amount of excess air intake required to maintain constant dryer outlet volume.

The excess air entering the dryer must be heated to the dryer discharge temperature of around 250°F. Normally, 18-20 percent of the total heat requirement is used to heat this excess air. By replacing this air with hot recycled stack gas, one could theoretically expect to reduce gas consumption by a similar amount. However, since the furnace operates on draft induced by the dryer fan, excessive volumes of recycled air would reverse the draft at the furnace and create problems. Therefore, the normal maximum amount of air that can be recycled is approximately 40% of the excess air requirement (25 - 30% of total dryer air volume); providing a 7 - 8% theoretical maximum saving in energy.

III. THE SYSTEM

An exhaust recirculation system was installed on one of two similar Heil SD 105-32 dryers at Parkland Alfalfa Products Ltd. The dryer is a triple pass rotary drum which contains a primary fan at the discharge end of the dryer for drawing in the air and alfalfa through the dryer. Air required for conbustion of the natural gas is provided essentially by a primary combustion fan; with a small proportion (approximately 10%) obtained from the incoming excess air.

The major component parts of the system were obtained from The Heil Co., with modifications made to suit our individual design specifications. The major consideration in modifying the design was to ensure adequate and continuous flow of air through the recycle duct to minimize buildup of fines and consequently reduce the risk of fires. To this effect, the recycle duct diameter was reduced from 24" to 20", and an auxillary fan was installed to ensure adequate air velocity. A vent stack with damper was installed at the discharge end of the recycle duct as a bypass to ensure continuous flow of recycled exhaust through the recycle system at all times. The inlet to the furnace was made to enter from underneath in order to prevent back-up of heat from the furnace, due to chimney effect, which could create fires in the recycle system in the event of an emergency shut-down or electrical failure of the primary dryer fan. The recycle duct was insulated to minimize temperature drop that could lead to condensation and buildup of fines within the duct. Additional details of the system are presented in Appendix I.

IV. PRINCIPLE OF OPERATION

A passive scroll-type skimmer, which is placed on the dryer exhaust stack, picks up exhaust air and diverts it through the recycle duct. From the discharge end of the recycle duct, the air enters the auxillary fan which is discharged to a "Y" splitter. Two dampers are attached; one at each end of the "Y". One end of the "Y" delivers the exhaust gas to the furnace inlet, while the other is attached to the vent stack. The dampers function opposite to each other such that if no exhaust gas was entering the furnace, it would be discharged out the vent stack. Consequently, recycled stack gas can flow continuously through the recycle system. The dampers are modulated automatically so that a constant negative pressure is maintained within the furnace. Adjustable shrouds were installed on the furnace opening around the burner to reduce the excess air intake, thereby facilitating maximum amount of recycle. These shrouds are adjusted manually to obtain a negative pressure of 0.1" WC at the furnace when the dryer is operating under maximum evaporation load when the recycle damper is closed.

V. RESULTS OF STUDY

a) Operation of System

Initially, fires occurred within the system, which were later identified as being caused by occasional sparks from the dryer exhaust igniting particulate material that had accumulated inside a sharp bend between the auxillary fan and transition to "Y" assembly. These smoldering pieces of material were blown out the vent stack and caused fires around the yard site and mill equipment. The problem was solved by eliminating the sharp bend and by insulating the auxillary fan and "Y" assembly.

The vent stack would accumulate a significant amount of fines, particularly under operating conditions that required very little air to be delivered out the vent stack (i.e. low moisture chops and suncure production). This, however was not considered a serious problem and could be corrected by installing a narrower diameter vent stack. The vent stack, which was the same diameter as the recycle duct (20"), could be reduced to 16" diameter, since normally a smaller portion of recycled air passes through the vent stack than through the furnace outlet.

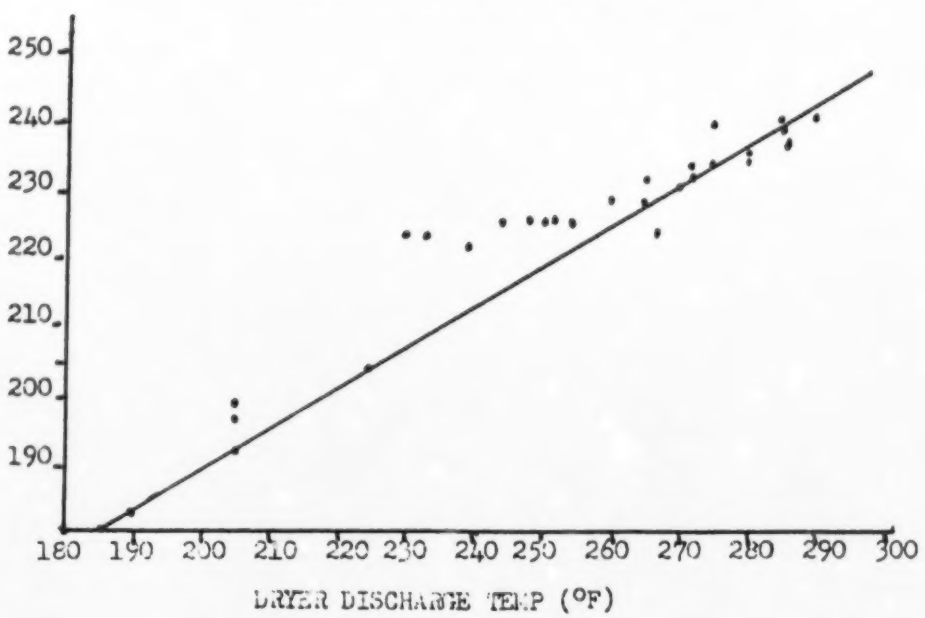
No adjustments to the dryer and burner controls were necessary for satisfactory operation. It is worth noting, however, that the dryer with the recycle unit produced dry chops containing approximately 1 percentage point lower moisture than the dryer without the recycle system, suggesting that the operators could have reduced the dryer discharge set point temperature relative to its usual setting prior to installing the recycle system. These observed differences, however, were based on a linited number of comparisons, and they may not necessarily have been real differences. The recycling of stack gas had no apparent positive or negative effects on dryer throughput rate.

b) Monitoring Activites and Their Results

A total of twelve separate test periods of 4-6 hr duration each were conducted during the production season. During each test run, samples of incoming and outgoing product were obtained from each dryer to determine their moisture content. These values, along with production rate, were used to determine the amount of water evaporated by each dryer. Additional information (1) natural gas consumption, (2) dry-bulb temperature of dryer discharge air, recycle air and furnace temperature, (3) wet-bulb temperature of dryer and recycle discharge air and (4) air flow through dryers and recycle system) was collected at the same time. Product samples were also collected for nutrient analysis. In addition, plant personnel recorded natural gas consumption and production levels on a 12 hr. shift basis over the season to provide additional information on a longer term basis.

Comparison of dryer exhaust temperature with recycle exhaust temperature is presented in Fig. 1. It shows that a maximum drop of approximately 50°F occurred within the recycle duct when the dryer was operating at maximum discharge temperature of 290 - 300°F. At dryer discharge temperatures of 200°F or less, the temperature drop in the recycle duct was negligible. Therefore, the heat loss from the insulated recycle duct ranged from 0 - 15% depending on the operating temperature of the dryer. The temperature of the recycle air was always substantially high enough so as to prevent condensation within the recycle air. In all cases, the recycle air would have had to decrease by an additional 50 - 80°F before condensation would occur. However, one must bear in mind that the interior surface of the duct is always somewhat cooler than the air passing through it. The lack of insulation initially around the auxillary fan area probably resulted in a sufficiently cool interior metal surface to cause condensation.

Figure 1: Comparison of recycle duct discharge temperature with dryer discharge temperature.



The recycle duct discharge air velocity was measured at 5400 ± 200 fpm; which was considered to be satisfactory. Most equipment manufacturers recommend a minimum of 4,500 - 5,000 fpm air flow through ducts for proper conveyance of alfalfa meal. One would suspect that the handling characteristics of the particulate material passing through the recycle system to be similar. Air velocity measurements taken when the auxillary fan was shut off reduced the air velocity by 300 - 400 fpm which may reduce velocities to borderline of what is recommended.

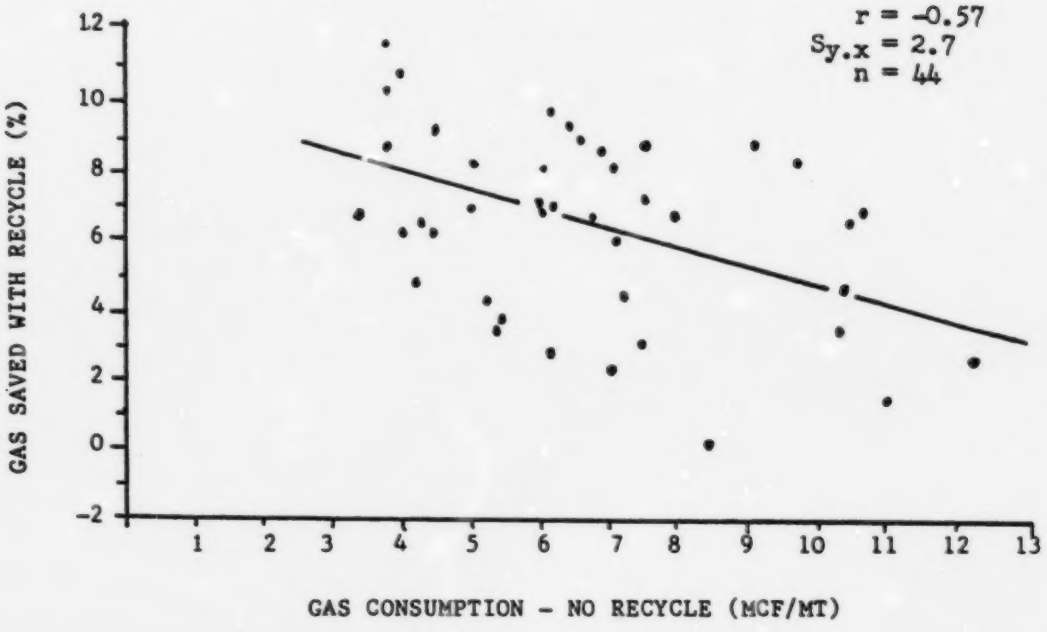
The volume of air passing through the recycle duct was 12,000 ± 1,000 CFM. The maximum attainable volume actually entering the furnace was 10,800 CFM. The reason for this difference was that the damper alignment was such that they could not be completely opened or closed. This was necessary to ensure that there was always some air passing through the furnace inlet manifold to prevent the metal from becoming exceedingly hot.

The effect of stack gas recycle on energy savings achieved are presented in Fig. 2, which presents data based on plant production records, and more precise tests that were conducted during the season. The comparisons were made on the basis of gas consumption (MCF natural gas consumed/MT of finished product); a unit more familiar to the industry. This data is presented along with additional information in Table 1.

Small differences are apparent between production data and test data; with the test data showing a slightly higher percentage in savings under low gas consumption and slightly lower gas savings under high gas consumption. These differences are probably due to the fact that data collected during the tests were more precise; while production data assumed that dryer throughput rates, evaporation loadings, etc. were equal for both dryers; although not measured. The percent energy saved is inversely related to the amount of water that is required to be evaporated. Higher moisture alfalfa chops being fed to the dryer increases the dryer evaporation load and, of course, the amount of natural gas required to dehydrate the alfalfa.

Figure 2. Natural gas savings with stack gas recycle.

A. PRODUCTION DATA



B. TEST DATA

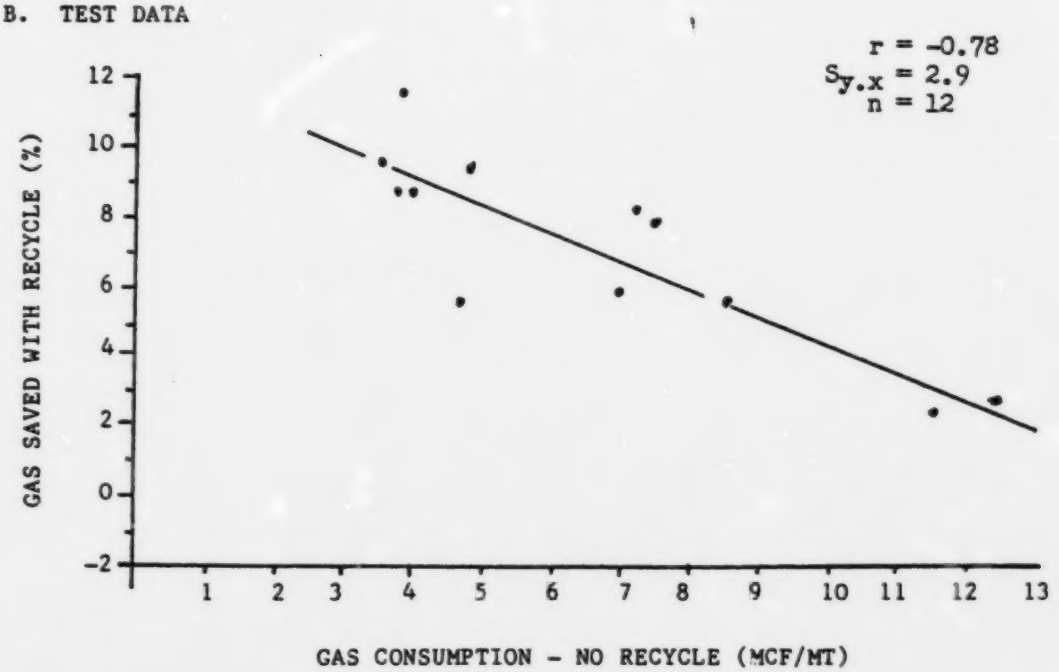


Table 1. Natural gas savings with stack gas recycle under various dryer load conditions.

NO RECYCLE			NATURAL GAS SAVINGS WITH RECYCLE			
Evaporation Load lb/hr	Wet Chops % Moisture	Gas Consumption MCF/MT	Production Records MCF/MT	Production Records %	Tests MCF/MT	Tests %
8,500	49.6	3.0	0.26	8.7	0.30	10.1
11,500	57.1	5.0	0.38	7.6	0.43	8.5
14,500	64.6	7.0	0.44	6.3	0.48	6.9
17,500	72.1	9.0	0.47	5.2	0.48	5.3
20,500	79.6	11.0	0.46	4.2	0.40	3.6

As was explained previously, a higher evaporation load reduces the excess air requirement, and therefore reduces the amount of exhaust gas that can be recycled. This is illustrated in Fig. 3 where the exhaust volume recycled varies from 10 - 28 percent of the total dryer air requirement of 38,000 CFM. Consequently, the percent energy saved varies with the volume recycled.

A comparison of theoretical vs. actual energy savings is presented in Table 2. Actual savings are slightly higher than what is theoretically expected. This difference possible lies in the fact that the increased humidity content of the drying air prevents "case hardening" where the surface of the alfalfa particles become so dry that moisture migration from the centre is retarded, and hence drying efficiency is reduced.

Table 2. Comparison of theoretical vs. actual saving of energy in stack gas recycle.

Evaporation Load lb/hr	Percent Natural Gas Saved with Recycle	
	Theoretical	Actual
6,000	8.4	10.6
12,000	6.0	7.7
16,000	4.5	5.9
20,000	3.0	4.0

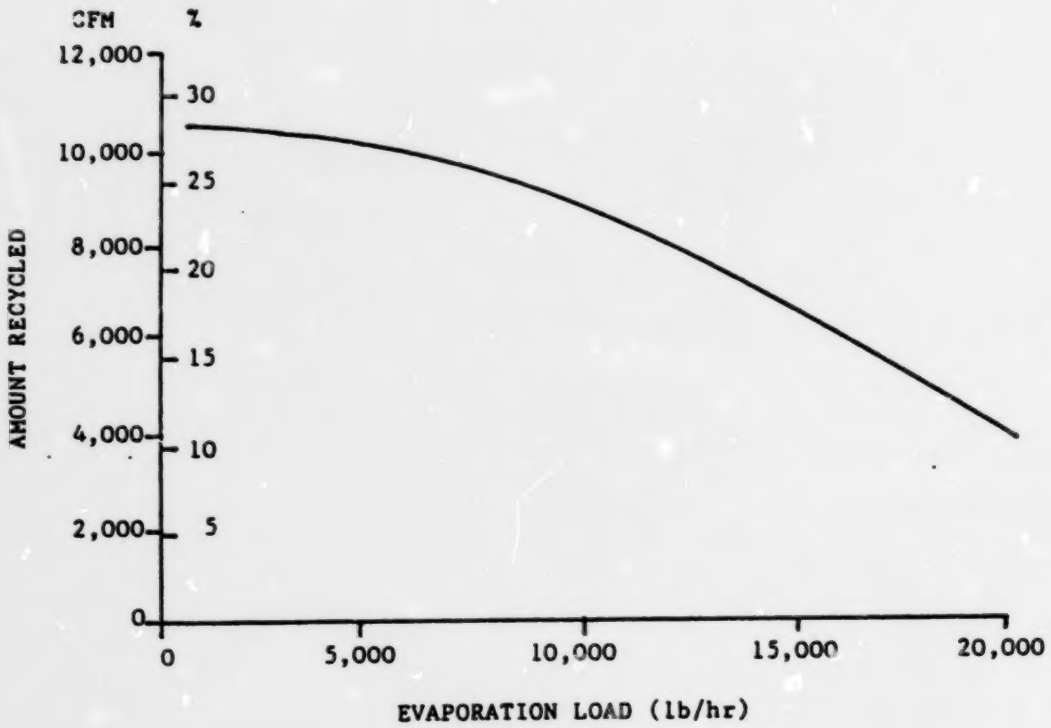


Figure 3. Effect of evaporation load on amount of air recycled.

No actual tests were conducted during suncure production. However, based on a calculated theoretical savings of 13.3%[1] and average natural gas consumption of 1.1 MCF/MT, a saving of 0.15 MCF/MT would be achieved. Analysis of product samples collected revealed no effect of recycle on product quality (Table 3). No measurements were obtained on the effect of recycle on stack gas particulate emission reductions at the time of this writing.

Table 3. Effect of stack gas recycle on product quality.

	Carotene (mg/lb)		Crude Protein (%)	
Sampling Period	Recycle	No Recycle	Recycle	No Recycle
1	78.3	81.2	17.1	17.0
2	85.3	82.8	18.7	18.6
3	93.8	98.8	18.2	18.4
4	100.0	97.0	17.6	17.3
Average	88.1	89.0	17.8	17.7

VI. ECONOMIC ASSESSMENT OF STACK GAS RECYCLE

The payback period for the system is presented in Table 6 based on an annual gas savings as presented in Table 4 and a capital investment of $30,000 (Table 5). These calculations do not take into consideration electrical costs (estimated @ $400 in 1982) nor maintenance which would be minimal. Also, capital cost allowance for depreciation which would increase the after-tax savings has been excluded. On the basis of average gas consumption levels of 3, 5 and 7 MCF/MT, the payback period has been determined at 4.6, 3.2 and 2.8 years respectively.

Although natural gas savings achieved during the suncure operation are substantially lower than when producing dehy, the amount saved could shorten the payback period by 10 - 15 percent, depending on the annual volume of suncure production. In 1982, for example, an output of 3,000 MT of suncure from one dryer would have reduced natural gas costs by $1,330.[2]

1. Determined by sensible heat or useable heat which was calculated from temperature and volume measurements of recycled stack gas.
2. 0.15 MCF natural gas saved/MT @ $2.95/MCF x 3,000 MT.

Table 4. Annual natural gas savings with stack gas recycle.

Gas Consumption MCF/MT	Gas Savings[a] MCF/yr
3.0	2,520
5.0	3,645
7.0	4,140
9.0	4,275
11.0	3,870

a. Calculated from average of production and test data, and 9,000 MT annual production for 1 dryer.

Table 5. Capital cost of stack gas recycle system for Heil SD 105-32 dryer.

Basic equipment package: -Skimmer, ductwork, auxillary fan, insulation, damper assembly and controls	$22,000
Other materials: -supports, electrical wiring, brick, hardware, etc.	2,000
Labour: -installation, electrical, brickwork, crane rental	4,500
Customs, freight and misc.	1,700
TOTAL	$30,200

Table 6. Calculation of payback period with stack gas recycle.

ASSUMPTIONS:
1. Natural gas price will increase @ 15%/ann.
2. Money borrowed for capital purchase @ 15%/ann.
3. Cost of electricity and maintenance are excluded in calculations

Natural Gas Consumption:		3 MCF/MT	5 MCF/MT	7MCF/MT
1982	Capital Investment	$30,000	$30,000	$30,000
	Interest @ 15%	4,500	4,500	4,500
	Gas savings @ $2.95/MCF	(7,430)	(10,750)	(12,200)
		$27,070	$23,750	$22,300
1983	Capital investment bal.	$27,070	$23,750	$22,300
	Interest @ 15%	4,060	3,560	3,350
	Gas Savings @ $3.40/MCF	(8,570)	(12,390)	(14,080)
		$22,560	$14,920	$11,570
1984	Capital investment bal.	$22,560	$14,920	$11,570
	Interest @ 15%	3,380	2,240	1,740
	Gas savings @ $3.90/MCF	(9,830)	(14,220)	(16,150)
		$16,110	$ 2,940	$(2,840)
1985	Capital investment bal.	$16,110	$ 2,940	$(2,840)
	Interest @ 15%	2,420	440	-
	Gas savings @ $4.50/MCF	(11,340)	(16,400)	(18,630)
		$ 7,190	$(13,020)	$(21,470)
1986	Capital investment bal.	$ 7,190	$(13,020)	$(21,470)
	Interest @ 15%	1,080	-	-
	Gas savings @ 5.15/MCF	(12,980)	(18,770)	(21,320)
		$(4,710)	$(31,790)	$(42,790)
Payback period		4.6 years	3.2 years	2.8 years

VII. SUMMARY AND CONCLUSIONS

A stack gas recycle system was installed and evaluated at Parkland Alfalfa Products Ltd., Zenon Park, Sask. to assess its performance in the drying of alfalfa under conditions typically found in the alfalfa dehydrating industry in Saskatchewan. The study was conducted by the Alfalfa Dehydrators Research Laboratory, Tisdale, Sask; with financial assistance from the governments of Saskatchewan and Canada.

Problems with the occurence of fires as caused by particulate material accumulation inside the system were experienced initially. This problem was solved by eliminating "dead air" spots inside the ductwork and by the installation of additional insulation to prevent temperature decrease of metal surfaces and hence condensation.

The velocity of stack gas passing through the recycle system was 5,400 $\pm$ 200 fpm, which was considered to be satisfactory. The volume of air passing through the recycle duct was 12,000 $\pm$ 1,000 CFM. Of this amount, the volume entering the furnace ranged from a low of 4,000 CFM to a high of 10,800 CFM, representing 10 - 28 percent of the total dryer air requirement. The volume that could be recycled was inversely proportional to the evaporation loading on the dryer, which consequently affected the energy savings achieved. The energy saved ranged from a low of 4.0% under high evaporation load (high moisture feed) to a high of 9.4% under low evaporation load (low moisture feed). These savings were slightly higher than what was theoretically expected; the difference which was probably due to the higher humidity of the drying air improving drying efficiency. Although no tests were conducted on suncure material, theoretical natural gas savings of 13.3% was determined from the sensible heat content of the recycle stack gas.

The saving of natural gas was 2,500 - 4,000 MCF/season based 9,000 MT production of dehy/ann. On the basis of a capital investment of $30,000, investment payback period ranged from 2.8 - 4.6 years depending on the average level of gas consumption/MT finished product. Savings achieved during suncure production could reduce the payback period by 10 - 15 percent.

The system had no apparent positive or negative effects on the performance of the dryer prior to recycle system installation. There was no improvement in product quality (carotene and crude protein content) with recycle. No measurements were taken to determine if particulate emissions were reduced.

In conclusion, the results of this study have shown that stack gas recycle systems can be successfully implemented under conditions typically found in the alfalfa dehydration industry in Saskatchewan if proper consideration is given to equipment design, installation and operation. The saving of natural gas used for drying is of sufficient magnitude that, based on projected natural gas prices, the relatively short payback period of the capital investment makes stack gas recycle sufficiently attractive as a means of reducing the cost of drying in the alfalfa dehydration industry.

VIII. RECOMMENDATIONS FOR FUTURE INSTALLATIONS

As a result of the knowledge and experience gained as a result of this study, the following recommendations are made for consideration in future installations.

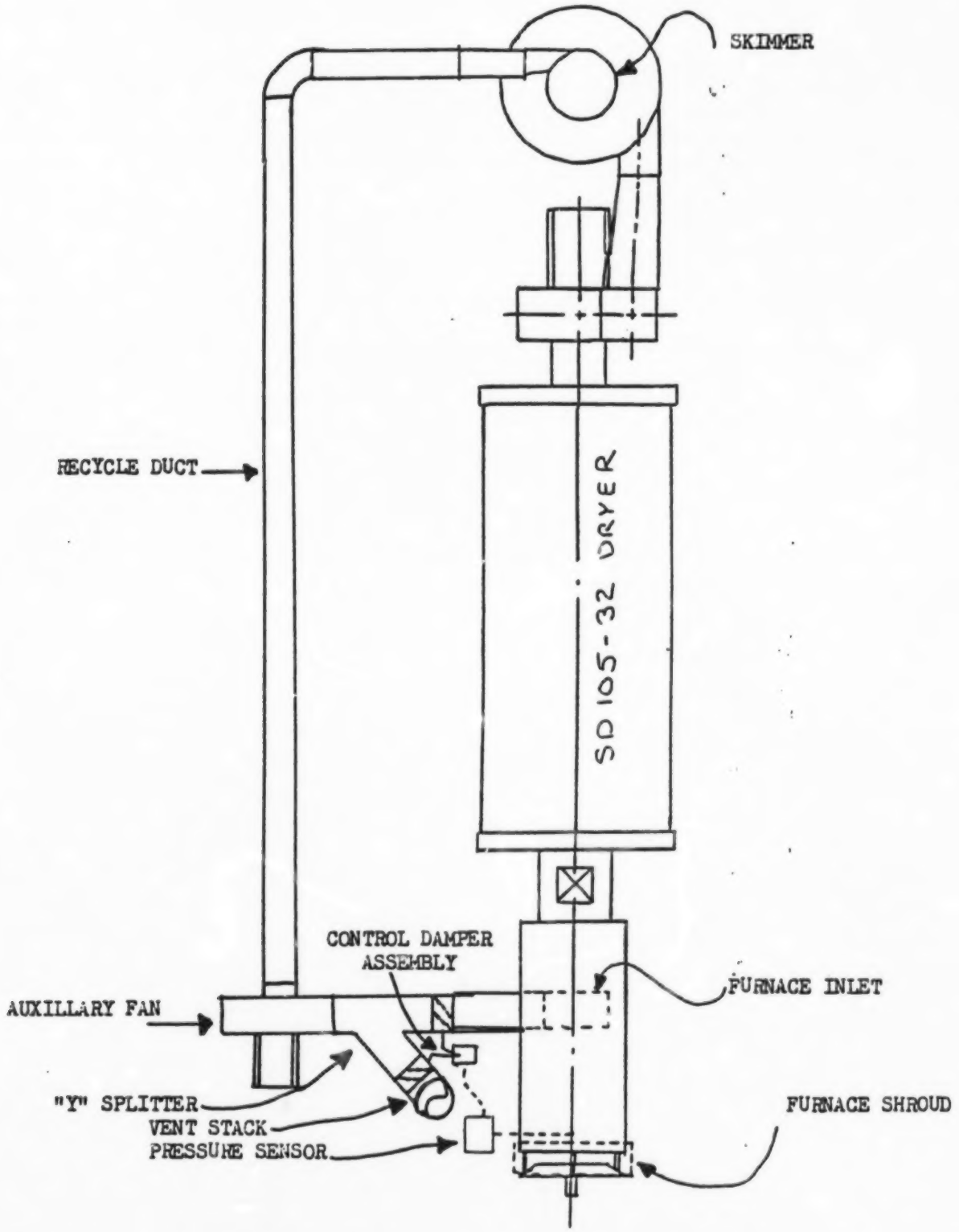
1) In view of the problems experienced with condensation, the accumulation of particulate material and the occurence of fires, it is important to ensure that air flow through the system be at least 5,000 fpm, that air flow be smooth and continuous and that temperature decrease of the recycled air and, in particular, the metal surfaces of the system be minimized. To this effect, duct diameter should be of a size to maintain proper air velocities, and all ductwork, elbows, transitions, etc. be constructed to ensure smooth air flow with no dead air pockets. Insulation of 2" thickness should cover all exposed metal surfaces, including the recycle duct, auxillary fan, transitions and "Y" splitter. The vent stack bypass is an important feature to ensure continuous flow of air through the recycle duct. Vent stack diameter can be reduced relative to the diameter of the recycle duct in order to facilitate adequate velocity of air through the stack. In the particular installation made, this stack diameter could be reduced to 16" from its existing diameter of 20".

2) An auxillary fan is probably not essential on dryers that operate on negative air systems (i.e. MEC equipment). The recycled air can be taken from the outer fan scroll of the primary collector fan where the high air pressure from the fan would maintain adequate air velocity through the recycle duct.

3) The entry point of the recycled air back into the drying system is critical to the extent that it must not interfere with the combustion of natural gas. Stack gas contains low oxygen levels, and therefore would retard combustion if introduced around the burner assembly. An inlet half-way down the furnace tube eliminates any interference with combustion, and secondly, burns off any particulate material that might be contained in the recycle air. The inlet into the furnace should be made from underneath; as a "chimney effect" after shut-down or emergency failure of the drying system could result in heat backing up the recycle duct and causing a fire within the duct if the entry into the furnace was made from the top.

4) Considering the constant variation in dryer operation as affected by changes in moisture content of incoming feed, dryer loading, etc., the amount of stack gas recycled can change quite dramatically during the course of operation. Under these conditions, automatic modulation of the damper is highly desireable; firstly, to prevent any upset in the dryer pneumatics balance, and secondly, to ensure that maximum amount can be recycled at all times. Modulating the damper by means of a sensor that measures the negative pressure at the furnace is the preferred method of control. This is particularly important for venturi-type atmospheric pressure burners; as these burners rely largely on incoming air from the excess air intake to complete the combustion of natural gas.

APPENDIX I: SCHEMATIC DIAGRAM - STACK GAS RECYCLE SYSTEM



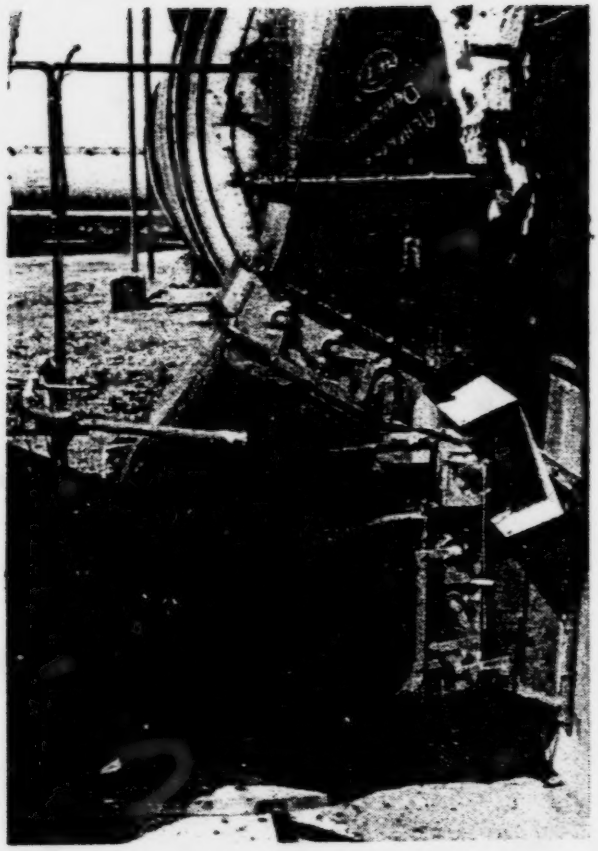
Component Parts of Exhaust Gas Recycle System

1. Skimmer - passive scroll-type
2. Recycle duct - 20" diameter, 14 ga.
   - c/w 2" insulation, weather protected
3. Auxillary fan - Chicago Blower, 12,000 CFM
   - 10 HP, 1800 RPM
4. "Y" splitter - 12 ga.
   - c/w 2" insulation, weather protected
5. Control damper assembly w/motor operator.
6. Pressure sensor assembly - furnished by Heil Co.
7. 20' vent stack - 20" diameter, 14 ga.
8. Furnace inlet manifold - 3/16" HRS, bricklined
9. Furnace shroud - 18 ga. galvanized iron

STACK GAS RECYCLE SYSTEM AT PARKLAND ALFALFA PRODUCTS LTD.

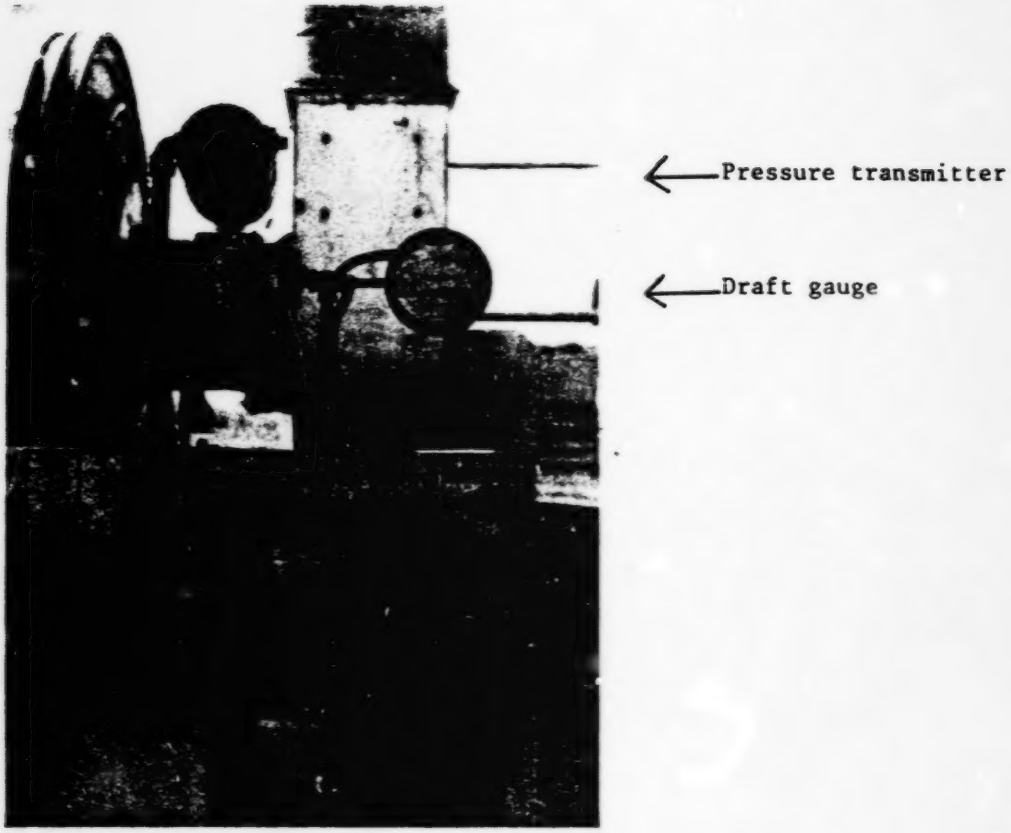
General view of recycle system

General view from front end of dryer
-note auxillary fan, Y splitter and damper assembly

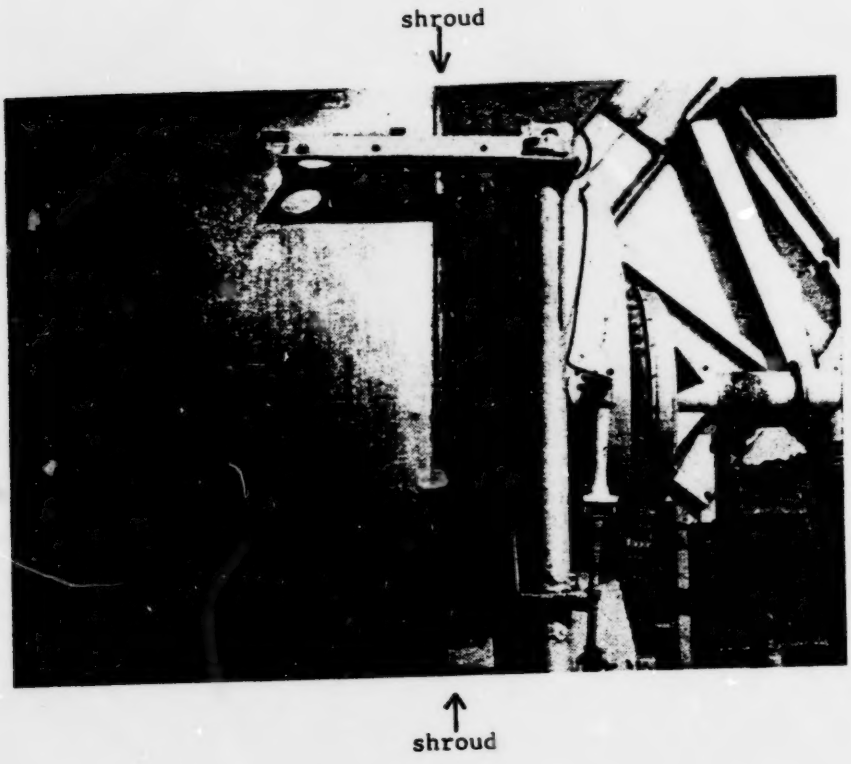


Close-up of Y splitter and damper assembly

Skimmer and recycle duct



Draft (negative pressure) gauge and pressure transmitter for controlling damper position



Burner shrouds and copper line for monitoring negative pressure in furnace

Inspection plate on recycle manifold (opposite side of damper assembly)